# IMPROVEMENT ON THE GROWTH OF ULTRANANOCRYSTALLINE DIAMOND BY USING PRE-NUCLEATION TECHNIQUE

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## Abstract

Diamond and related materials have many potential applications due to their marvelous physical and chemical properties. However, most of the applications require smooth surface. The difficulty in polishing the diamond films frequently hinders the development of device applications. Moreover, the applications such as surface acoustic wave (SAW) devices require relatively thick diamonds films, which call for a high growth rate process. In this study, ultrananocrystalline diamond (UNCD) films, which possess very smooth surface, were synthesized using $CH_4$/Ar plasma. The Si-substrate was pre-nucleated using bias enhanced nucleation (BEN) technique under $CH_4/H_2$ plasma, so that the growth of UNCD films can be markedly enhanced. The UNCD films were grown in a 2.45 GHz microwave plasma enhanced chemical vapor deposition (MPECVD) system. The growth rate of these UNCD films were observed to be correlated intimately with the deposition conditions, such as substrate temperature, microwave power, total pressure, $CH_4$ ratio. The nucleation process was carried out under methane and hydrogen ($CH_4/H_2$) plasma with negative DC bias voltage. No pretreatment on substrate was required prior to the formation of diamond nuclei. The growth kinetics of BEN induced nuclei was monitored by the evolution of the bias current to ensure the full coverage of diamond nuclei on the Si-substrate. The average grain size of BEN induced diamond nuclei is about 30 nm (Fig. 1), with the nucleation site density more than $10^{11}$ sites/cm$^2$. The thickness of BEN induced diamond nuclei layer was about 250 nm. The growth rate of UNCD is markedly enhanced due to the application of BEN induced nuclei. Moreover, the growth rate of UNCD films was more significantly affected by the substrate temperature, but was less influenced by the microwave power. All of these UNCD films showed similar morphology, i.e., with grain size less than 10 nm and surface roughness around 20 nm (Fig. 2). They also possess the same Raman spectra, i.e., the same crystallinity. However, the deposition rate can be increased from about 0.2 μm/hr to 1.0 μm/hr when substrate temperature increased from $400^0$C $600^o$C. How the characteristics of these UNCD correlated with their electron field emission properties will be discussed.

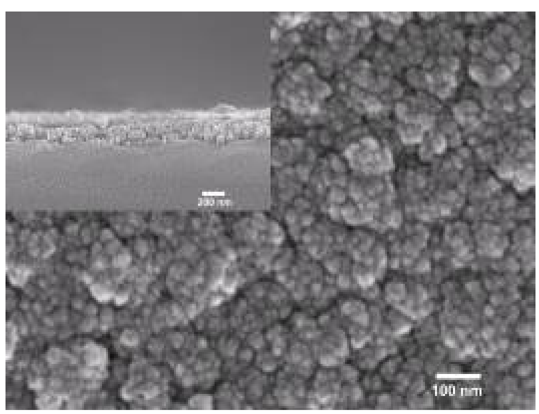


***Figure 1. SEM surface morphology of BEN nanodiamond with the inset showing the cross-section.***

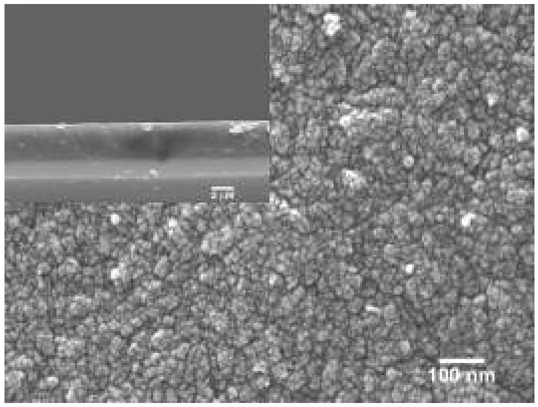


***Figure 2. SEM surface morphology of UNCD grown under 600$^o$C, 3 hr with the inset showing the cross-section.***

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